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NASA SKYLAB / EREP
Fourth and Fifth Quarterly Progress Report
Contract NAS 8-29617 EPN 507
Application of Multispectral Photography to Mineral and Land Resources of South Carolina

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INTRODUCTION

Bulk transparencies of good to excellent photographic quality from both S190A and S190B were received from Skylab 3. Geologic interpretation, based upon past and present mapping of rock units in northwestern South Carolina was applied to these photographs, and a limited commentary on geologic features in eastern South Carolina, were made from the S190B photographs (fig. 1).

Color infrared bulk transparencies of very good quality, nearly cloud-free, were received from a NASA U-2 flight parallel to the entire South Carolina coastline. A summary of the data products received is presented in Table 1.

Written descriptions of geologic analyses were furnished by co-investigators Villard S. Griffin, Jr. and Robert D. Hatcher, both geology professors at Clemson University. Dr. Hatcher prepared the geologic description and evaluation of frame 352, magazine 88, ground track 33, EREP pass 7 (descending). Dr. Griffin made a similar analysis of frame 285, magazine 86, ground track 43, EREP pass 36 (ascending). The Geography Department staff at the University of South Carolina was very helpful in providing work space and equipment for the writer. Finally, special thanks are due to Mrs. Jacqueline Brown, Division of Geology, South Carolina State Development Board for typing the manuscript.

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Table 1. Skylab/EREP (SL 3) and high altitude (U-2) aircraft photography over South Carolina and adjacent states received from NASA during fourth and fifth quarterly reporting periods, 1974.

Sensor	Image Size	Scale (approx.)	Conversion factor* 1:500,000 base map	EREP pass / ground track	Film magazines / frames
S190A Multispectral Camera Facility	2 1/4 X 2 1/4 in. (contact)	1:2,800,000	5.6	36/43	37-42/ 109-118
	9 X 9 in.	1:700,000	1.4	46/43 (Same as Contracts)	43-48/ 102-111 (Same as contacts)
S190B Earth Terrain Camera	4 1/2 X 4 1/2 in.	1:1,000,000 (closer to 1:933,000)	2.0	7/33	81/348-365
	9 X 9 in.	1:500,000	1.0	36/43 46/43	86/284-294 88/143-151
Conventional camera	2 1/4 X 2 1/4 in.	1:500,000	1.0	(Not applicable)	(Not applicable)

*Multiplication factor needed to plot ground tracks and frames from transparencies to South Carolina base map (USGS, scale 1:500,000).

Remarks

All data products bulk transparencies, overall quality excellent, mostly less than 30 percent cloud cover, all over track 43 (Clark Hill Reservoir to Pee Dee River and beyond). Data products, in sequence, for magazines 37-42 as follows: b/w IR pos; b/w IR neg, color IR, color, b/w pos and b/w neg, and b/w pos. Identical kinds of photographs received from magazines 43-48. All photographs from EREP passes 36 and 46 received on both contacts and 4x enlargements.

Marginal data on contact transparencies for Pass 7 mispunched as mag 88 -- should be mag 81, according S190B map of United States. Overall quality on Pass 7 fair, mostly greater than 30 percent cloud cover, colors somewhat overexposed (higher sun angle?). Frames 348-351 in Appalachians of North Carolina (greater than 75 percent cloud cover); frames 352-359 extend from Charlotte-Gaffney area to Myrtle Beach - Georgetown area; frames 360-365 all over Atlantic Ocean.

Overall quality on Pass 36 roll 86, good to excellent. Frames 284-288 extend from Savannah River (Clark Hill Reservoir) to Charlotte-Rock Hill area with excellent quality, less than 30 percent cloud cover; frames 289-294 extend from Charlotte area to North Carolina-Virginia line (Roanoke R.).

Overall quality on Pass 46, roll 88, fair to good; some areas slightly overexposed; cloud cover approximately 20 to 25 percent over South Carolina (frames 146-148), greater over other areas.

All photographs from EREP passe 7, 36 and 46 received on both contacts and 2x enlargements.

Total length of flight line extends from North Carolina line to Savannah Beach, Georgia; 29 frames of bulk color IR transparencies. Altitude of U-2 aircraft reported as 65,000 feet; area of ground coverage per frame = 16 X 16 miles (approximately). Flown in mid-September under nearly cloud-free conditions. Color IR quality good to excellent but all features appear to be slightly out of focus. See land resource applications in summary.

Geologic Interpretation

General Comments

There are significant differences in various types of features in the S190B color photographs. Structural features which are imprinted onto the topography may be readily seen. For example, the Brevard fault is faintly visible in photos 350 and 351 through the clouds. Valley and Ridge structures are visible in part of frame 348. Many lineaments, likely joint controlled, are also visible, as in frames 286, 351 and 352.

Soils appear to be very excellent indicators of rock types in the Piedmont in these photographs, as they are on the ground. The deep red soils visible in the photographs are likely indicative of biotite- and/or amphibole-rich rocks (biotite schists and gneisses, amphibole gneisses). Soils can be seen in areas where vegetation has been removed by farming or urban development, and much of the Piedmont is suitable for this type of analysis. Lighter colored soils are indicative of granitic rocks and/or rocks low in total iron. Granitic gneisses and granitic plutons are recognizable on this basis (for example, frames 284, 285 and 286). Soils should be used with caution as bedrock indicators, for soil color could also be controlled by geomorphic factors, such as overall relief of the area and the depth of groundwater (see detailed discussion of frame 352).

Rock units in the southeastern region of the United States have a long geologic history of chemical weathering in which decomposition is prevalent, whereas the exposed formations of the western United States have recorded long periods of physical weathering characterized by rock disintegration. Rock formations in the Southeast occur in a low-contrast terrain, that is, features subdued by abundant vegetation.

Development of roads and housing in rural areas is taking place along ridges and higher areas in the Piedmont, while development in more urban areas occurs more randomly (for example, frames 351 and 352). In many places in the more urbanized areas it appears that construction of housing or other structures has taken place in potentially hazardous areas. Large (50-or 100-year) floods would result in heavy property damage.

The overall drainage pattern developed in the Piedmont is random (see frames 351 and 352); yet, closer examination of meandering reaches of major and minor streams exhibits control by the joint-directed lineaments mentioned above.

SPECIFIC COMMENTS--FRAME 352

The area covered by frame 352 (fig. 2) includes Hickory, Charlotte and Shelby, North Carolina and Rock Hill and Gaffney, South Carolina. These frames cross parts or all of most of the major geologic provinces of the crystalline Southern Appalachians, including part of the Blue Ridge, the Brevard fault zone, Chauga belt, mobilized Inner Piedmont, Kings Mountain belt and most of the Charlotte belt (fig. 3). Physiographic provinces include part of the Blue Ridge and Piedmont which is divisible into an upper Piedmont and a more easterly lower Piedmont.

There are several strong lineaments present in this area (fig. 2, L-1). Rhodiss Lake and Lake Oxford, west and north of Hickory, lie on a strong nearly east-west lineament. One arm of Mountain Island Lake just west of Charlotte is on a N70°W lineament (fig. 2, L-2), as is the area of the Broad River north of Gaffney and southwest of Shelby (fig. 2, L-3). These are likely joint controlled but they are also parallel to zones of siliceous mylonite mapped and described by Conley and Drummond (1965) in this area. Similarly oriented zones of siliceous mylonite have also been described by Birkhead (1974) in Greenville County, South Carolina.

Northwest-southeast and northeast-southwest lineaments also are discernible in these photographs. Lake Wylie, south of Charlotte, and meanders of the Catawba River, along with several smaller drainages contain both northwest and northeast lineaments (fig. 2, L-4) as are also observed along the Broad River south of Gaffney (fig. 2, L-5). These likely reflect the regional systematic transverse and longitudinal joint pattern recognized in northwestern South Carolina by Acker and Hatcher (1970). A N10°W lineament direction was also observed. This also likely represents another major joint direction recognized by Acker and Hatcher (1970).

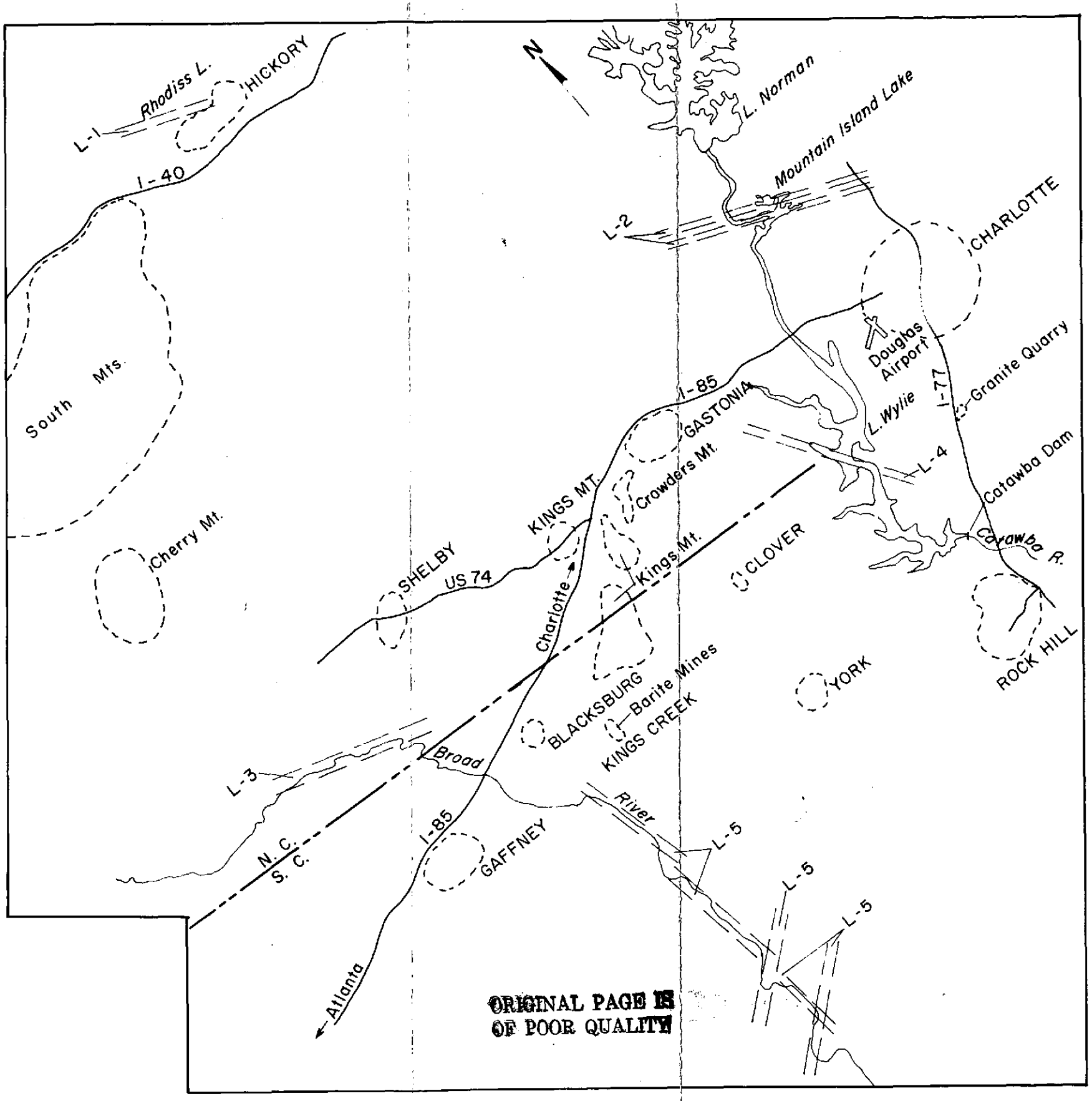
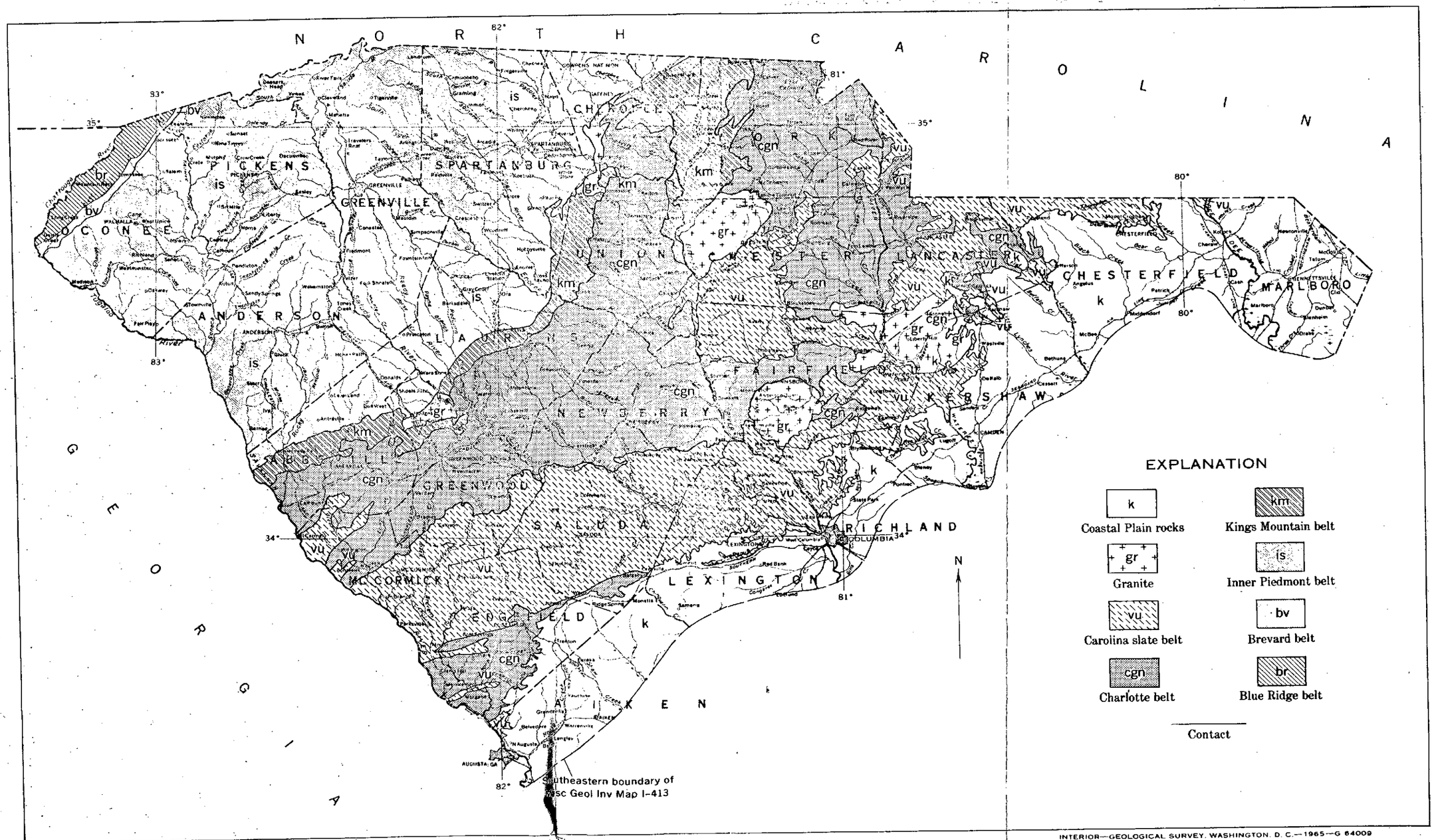


Figure 2. NASA Skylab 3 overlay to frame 352, magazine 88, ground track 33 EREP pass 7 (descending). Enlarge (2x) S190B color photograph; scale 1:500,000. L-1 through L-5 refer to lineaments described in text.



Base from U.S. Geological Survey State base map of South Carolina

Geology modified from Overstreet and Bell, 1965

INTERIOR—GEOLOGICAL SURVEY, WASHINGTON, D. C.—1965—G 64009

FIGURE 3 MAP SHOWING GEOLOGIC BELTS IN SOUTH CAROLINA

SCALE 1:1 000 000

The soils of the Piedmont when they are exposed probably allow for differentation of the various geologic provinces (fig. 3) represented in these photographs. The northeast-southwest trending belt of very red soils southeast of the Blue Ridge and northwest of the vegetated Kings Mountain are the iron-rich soils derived from weathering of the biotite and amphibole gneisses of the mobilized Inner Piedmont. The lighter soils southeast of Kings Mountain likely reflect the granitic plutons of the Charlotte belt. However, this may be a function of the change in relief, changes in drainage pattern and groundwater regime in the Charlotte belt. But, in general, this pattern is to some degree borne out by bedrock studies in this area by Keith and Sterrett (1931), Overstreet and others (1963a), Overstreet and others (1963b), Overstreet and Bell (1965), and Butler (1966). Likewise, the Charlotte belt in this area can be seen in the photograph (from Clover eastward) to have lower relief (swampy, otherwise poorly drained) and so some of these geomorphic factors may have a bearing upon the interpretation. Stream patterns and densities also change from a greater density of streams with well developed drainage basins in the mobilized Inner Piedmont to a lower stream density and streams which meander more in the Charlotte belt.

Land development patterns in the Piedmont are evolving along the routes of least resistance. Secondary roads are following the drainage divides, urban expansion is following the transportation arteries in decreasing order of importance. The more rugged areas of the Piedmont and Blue Ridge are experiencing lesser development at present.

SPECIFIC COMMENTS--FRAME 285

The area covered by frame 285 (fig. 4) includes the towns of Greenwood, Newberry, Laurens, Clinton, Abbeville and other communities, all in South Carolina. Principal natural features are the Savannah and Saluda Rivers; Parsons Mountain, Boles Mountain and Mt. Carmel, all monadnocks (erosional remnants); and Carolina bays (CB), elliptical depressions confined to the Atlantic Coastal Plain province.

The northwestern part of frame 285 covers an area discussed in a recent geologic report (Griffin, 1972). Main efforts in this analysis were directed toward determining if any geologic zones and structures discovered during the prior geologic mapping study were expressed in this Skylab photograph. Specifically, the preliminary geologic map of a major portion of Abbeville County and the northern McCormick County, South Carolina (Griffin, 1972), shown in fig. 5, was used as the geologic "ground truth" source, and a copy is included with this report for your reference.

Lineaments are very subtle in the photograph, and interpretations might differ significantly from one observer to another. However, major geologic features apparently have at least some photographic expression at high altitude. In the northwest the cataclastic Lowndesville (Kings Mountain) belt (fig. 3, LB) is recognizable on both sides of the Savannah River and probably continues northeastward across the photograph to the area south of Laurens (fig. 5).

Several other linear trends are associated with the Lowndesville belt, both on the northwest and southeast. On the southeast lineaments probably represent several northeast trending narrow cataclastic zones, apparently formed within the Charlotte belt in response to movements along the Lowndesville belt (fig. 5). Some trends in the eastern part of the photograph appear to splay eastward away from the main Lowndesville belt. Southeast of the Lowndesville belt easily defined lineaments become progressively sparser, and even speculative ones are not to be seen. This situation changes near the

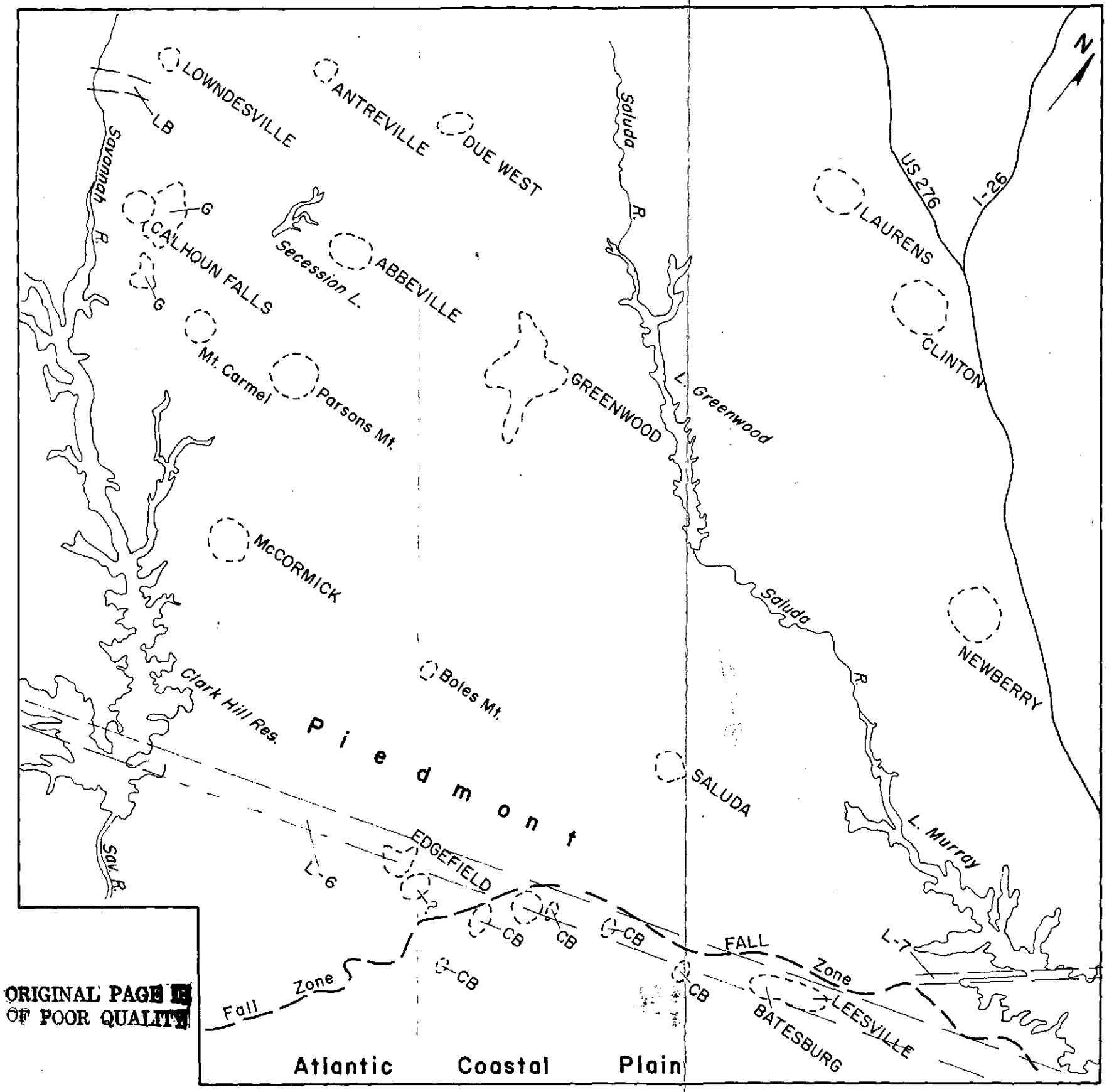


Figure 4. Overlay to NASA Skylab 3 frame 285, magazine 86, ground track 43, EREP pass 36 (ascending). Enlarged (2x) S190B color photograph; scale 1:500,000. L-B = Lowndesville Belt; CB = Carolina Bay; L-6 and L-7 = lineaments.

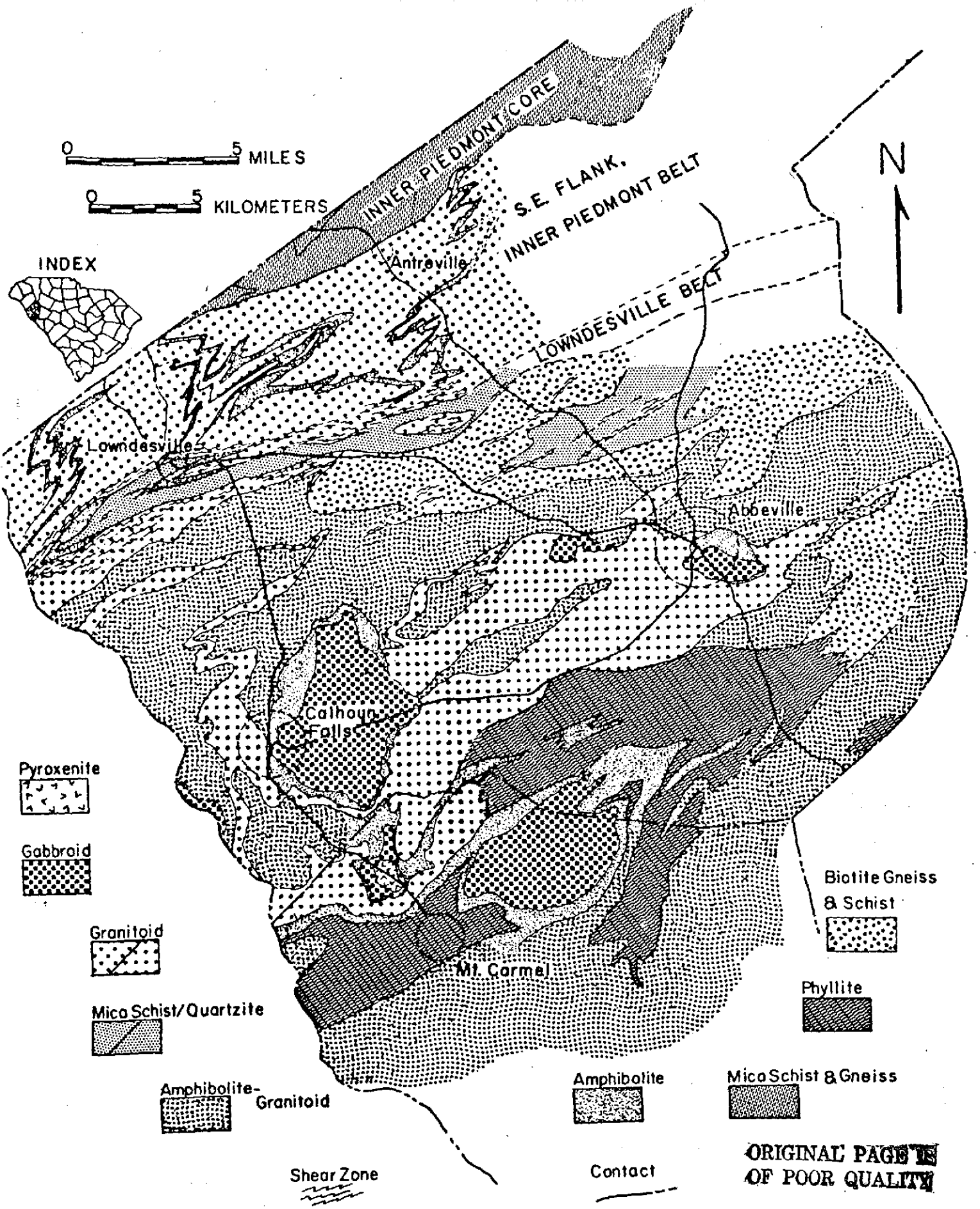


Figure 5. Preliminary geologic map of a major part of Abbeville County and northern McCormick County, South Carolina (from Griffin, 1972, p. 60).

southern border of the photograph. Here a very strong lineament (L-6) trend runs across the Savannah River from Georgia and extends with clear photographic expression to Lake Murray. A cataclastic zone, similar in character to the Lowndesville belt, occupies this lineament and has been reported by Tewhey (1973) in the Lake Murray area. Both W. A. Pirkle and V. S. Griffin, Jr. have observed it in Edgefield County.

Linear trends northwest of the Lowndesville belt generally have a more northeasterly direction, although between Due West and Laurens more easterly trends occur adjacent to the Lowndesville belt. The trends of the southeast flank of the Inner Piedmont belt (Griffin, 1972, p. 63, fig. 1) have less continuity than comparable features farther southeast (fig. 5).

The Calhoun Falls and Mt. Carmel gabbroid complexes (Griffin, 1972, fig.1) have expression in part within the photograph (fig. 3, G), as does the small satellite body immediately south of the Calhoun Falls complex. Gabbro is a dark rock composed mostly of aluminum silicates of calcium, magnesium and iron. The signature is no better than that seen on topographic maps with forest overlays, because extensive farming and pasturing are conducted in these fertile areas. The Abbeville gabbroid complex is not recognizable.

LAND - USE DESCRIPTION

Urban, forested, floodplain and water areas are obvious to the viewer of S190B transparencies, but all the foregoing areas are more sharply visible on S190A color IR transparencies although in less detail. Carolina bays and beach ridges are readily observed on EREP pass 7, ground track 33 in the Atlantic Coastal Plain (fig. 1).

Mining operations (fig. 2) can be located on S190B photography but the smaller mines and quarries were not observed partly because less bare soil is exposed and also dense vegetation can mask such smaller area activity.

Cultivated lands and pasture could not be distinguished visually but regular agricultural patterns, for example, could be observed in the valley of the Wateree River (EREP pass 7 ground track 33).

The nuclear power plant site in South Carolina for South Carolina Electric and Gas Co. and for Duke Power Co. is each located on Frame 287 (EREP pass 36, ground 43) on S190B. Preliminary engineering work has been done at the Duke site but SL3 photography clearly indicates the difference between little grading at the Duke site and the more advanced stage of construction at the SCE&G site.

Urban growth and economic development were compared for the Myrtle Beach area (fig. 6) by using special NASA U-2 color IR transparencies (Table 1). Enlarged prints (10x10 in) were obtained by our team and this increased the scale from 1:500,000 to 1:100,000. Unfortunately, the contact photographs were slightly out of focus, thus preventing detection of the more detailed land use in the area. Both the size of the urbanized area and its intensity have substantially increased since 1937, the edition of the USGS topographic base map (fig. 6). The U-2 color IR transparencies clearly show the tidal marshlands and the swampy inland areas, both of which affect the land-use patterns. Very little intense urban development has yet occurred inland from U. S. Highway 17 in the Myrtle Beach area.

CONCLUSIONS

GEOLOGIC APPLICATIONS

Any visual interpretation of satellite photography in the southeastern United States is aided greatly by color films. Decomposition of rock units in the Piedmont and the resulting iron oxides produces a reddish tint to most of the soils. Variations in the degree of oxidation of the iron-bearing minerals can be seen in the larger bare soil areas, as in the nuclear power plant site of South Carolina Electric and Gas Company (fig. 1, frame 287, S190B).

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Lineaments of major structural features are detectable but subtle. One actually has to have an intimate knowledge of the "ground truth" before a meaningful analysis is feasible. Thus the cart may have to come before the horse. However, it is possible that a geologist initiating a mapping study in the Piedmont could find this photography helpful as he maps, because it will point out some lineaments of potential major importance which could be checked out very early in the mapping. Actually, ERTS-1 imagery is more useful in detecting lineaments, but Skylab photography, especially S190A, has equal or greater potential by use of machine processing. In other words, our team feels that visual interpretation alone of Skylab photographs is very limited, and much of this is because of the low-contrast, heavily vegetated terrain in our part of the United States. Computer processing of multispectral photography (S190A), is the best hope. This was beyond the scope of our proposal. Future geologic applications for South Carolina should be centered around computer compatible tapes (CCTs) and some attempts at image ratioing.

LAND RESOURCE APPLICATIONS

Basic data for the main land resource application of this investigation came from the high altitude color infrared photography furnished by the NASA U-2 flight along the South Carolina coast (fig. 1). The U-2 color IR transparencies and the enlarged prints, already described, were used along with the 1968 U. S. Department of Agriculture black-and-white photo index to delineate land-use patterns in the Myrtle Beach area (fig. 6).

The U-2 transparencies were the first known color IR scenes available for the South Carolina coastline. They were not in sharp focus but perhaps this was the limit of resolution for both the camera and film at that altitude, 20,000m (65,000 ft). Future flights should verify this limitation because of the details required for land-use mapping. Furthermore, "ground truth" determination of level II land-use classification of Anderson and others (1972)--

not conducted by our EREP team--is necessary in preparing any detailed land-use map.

Skylab photography is useful for showing large areas of river floodplains, Carolina bays, karst terrain, beach ridges, marshlands, and hilly or mountainous topography--all natural land resources which must be considered in effective land-use planning and management. Skylab and associated aircraft photography provide unique combinations of sensors not available anywhere else, particularly in preparing a statewide land-use map. Computer techniques are definitely superior to visual methods, and these have good future operational potential when applied to level I land-use mapping using S190A multispectral photography.

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